**UNITED STATES ENVIRONMENTAL PROTECTION AGENCY**
ENVIRONMENTAL RESPONSE TEAM-WEST
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**MEMORANDUM**

SUBJECT: Red Hill Trip Report

FROM: Donald Bussey, CPG DTB
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TO: Steven Linder, P.E.
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The U.S. Navy Red Hill Fuel Storage Facility (Red Hill) is situated within solid rock (basalt) which forms a ridge east of Joint Base Pearl Harbor/Hickam, Island of Oahu, Hawaii. In early 2014 approximately 27,000 gallons of JP-5 jet fuel was released from Red Hill Tank 5. Other earlier releases have undoubtedly occurred. Red Hill is situated approximately 100 vertical feet above the local basil Koolau aquifer which has been designated as a sole-source aquifer. Large quantities of groundwater are produced daily from shafts and wells from this aquifer proximal to Red Hill in excess of 35 million gallons per day. Petroleum compounds have not been detected in groundwater samples collected from these water supply sources, although they have been detected directly below Tank 5.

The objective of the site visit conducted by U.S. EPA personnel on August 25 and 26, 2015 was to gather hydrogeological information and insight as to where the released product may have migrated.

The bedrock geology within which Red Hill was constructed are lava flows of the Koolau Basalt (Sherrod et al., 2007), deposited during the Pleistocene Epoch (approximately 1.8-2.6 million years ago). These flows can range in thickness from a few feet to a few tens of feet. Vesicular structures are formed near the top of most flows (Driscoll, 1989). As Gingerich and Oki (2000) state "*A typical sequence of lava flows contains both aa and pahoehoe flows. The interconnected void spaces in a sequence of pahoehoe flows may lead to high permeability. The layers of clinker at the top and bottom of aa flows also impart high permeability.*", and furthermore *"lava in the core of an aa flow typically cools as a massive body of rock with much lower permeability".*

Hydraulic properties within the lava flow deposits at Red Hill are determined by the distinctive textures and geometry of individual flows, which can be highly permeable. The flows are

anisotropic in three dimensions, with the highest permeability within the permeable portions of a flow in the longitudinal direction of the flow, an intermediate permeability in the direction transverse to the direction of lava flow, with the lowest permeability normal to lava flow (vertical permeability) (Hunt, 1996). There may be up to two orders of magnitude difference between permeability in the longitudinal direction, and vertical permeability (through vertical fractures within the core of aa flows).

Above the groundwater table of the Koolau aquifer petroleum product migration from the Red Hill release would be laterally within the more permeable zones, following the dip of the less permeable zones, as well as vertically downward through vertical fracturing of the less permeable zones. The magnitude of lateral migration is far greater than the vertical migration of free-phase LNAPL. Additionally, because each of the tanks at Red Hill are supported by a 20 Ft thick concrete foundation and an additional 2-4 feet of concrete encasing each tank, the footprint of Red Hill significantly limits vertical precipitation recharge directly beneath the Facility. Therefore, little recharge occurs through rock directly below Red Hill, minimizing the potential for dissolved-phase contamination migration to the aquifer below. In the unsaturated zone, movement of LNAPL initially is controlled by its fluid density and viscosity as it moves downward under the force of gravity. Subsurface heterogeneities may cause lateral spreading and trap lenses of LNAPL above layers of lower permeability during downward migration (Hunt et al., 1988).

As groundwater quality apparently has not been affected, as evidenced by the lack of detection of petroleum hydrocarbons, it may be deduced that little, if any, petroleum product is reaching the aquifer. While there may be a small volume reaching the aquifer, it is likely diluted by the huge quantities of groundwater removed daily. Also it may be deduced that the released product is likely mostly in the layers of permeable strata above the aquifer, and that vertical downward transport is minimal due to the many relatively impermeable horizontal layers. Lastly, petroleum hydrocarbons released into the environment are subject to weathering processes. As JP-5 weathers under aerobic conditions it increases in viscosity, which acts to retard migration to some degree. Relatively insignificant concentrations of BTEX in JP-5 are likely to limit environmental threats from JP-5 releases (USAF CEE, 2003).

Conventional remediation methods for JP-5 DNAPL removal are very limited. As there is no located LNAPL lens floating on the water table, hydraulic capture by depressing the water table for recovery is not an option. As there are minimal light end compounds (BTEX) in JP-5, vapor recovery by vacuum extraction also would be ineffective. Bioventing increases biodegradation via introduction of additional oxygen to enhance weathering may be an option, however the horizontal and vertical extent of LNAPL would need to be known, and locations for well installation for oxygen introduction would need be available.

There presently exists a small network of groundwater monitoring wells located between Red Hill and the groundwater withdrawal locations, several of these wells having recently been installed. Locations of these wells, and for any additional wells contemplated, are limited based mostly on the local terrain. These sentinel wells should provide a triggering mechanism to detect migration of free- and/or dissolved-phase contaminates moving towards the groundwater production locations. There are limited locations for placement of additional wells but it is

recommended that viable locations be determined and additional monitoring wells installed. To completely define the horizontal and vertical extent of free- and dissolved-phase contamination, many wells would need to be installed. This is very much complicated by terrain and Red Hill itself, and would likely be impracticable and very costly.

References

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Cc: Bob Pallarino
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